The Study on Lethality Simulation Method for Fragmentation Warhead

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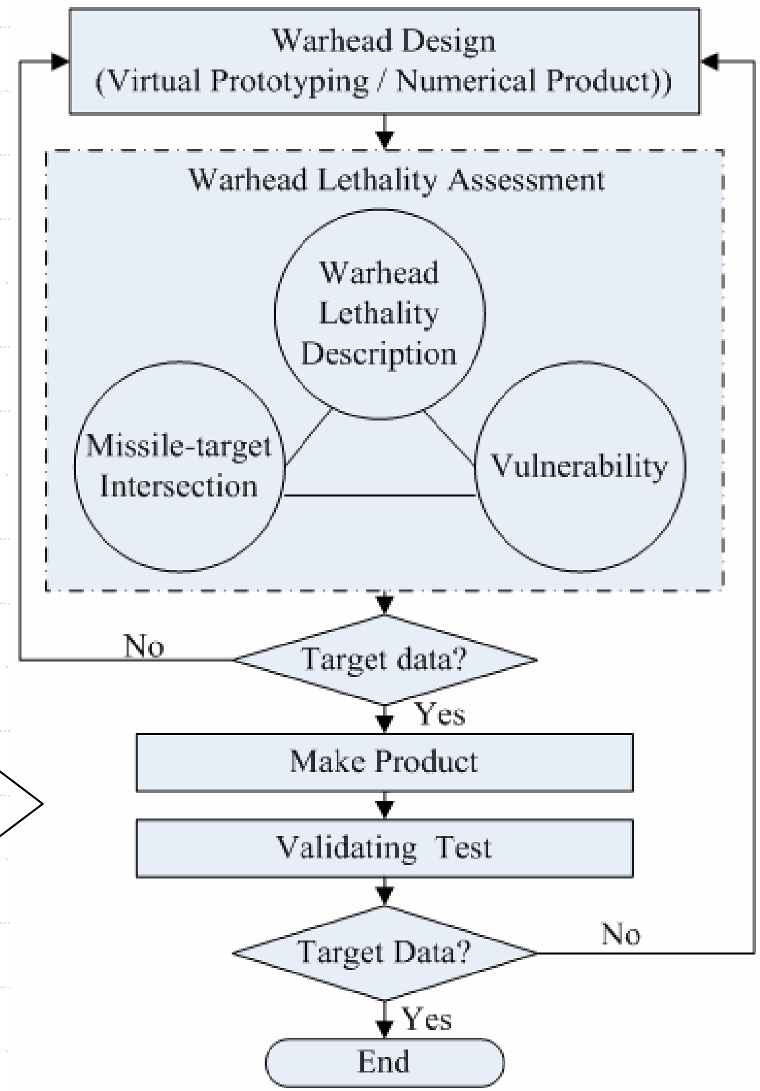
Table of contents

INTRODUCTION

☞ Warhead lethality assessment is an important factor of warhead study. It always includes warhead lethality description, missile-target intersection and vulnerability.



A work flow of warhead study

INTRODUCTION

- With the development of numerical simulation, many new methods of lethality assessment come forth

- Lethality test simulation could examine whether lethality target data is satisfied with design requirement before making the product, so development cycle is shorten and outlay is reduced.

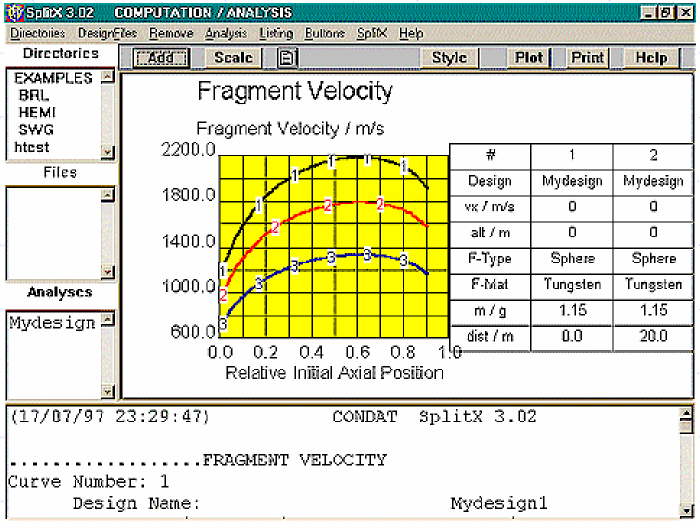
- Test method, analytical method and numerical simulation method are widely adopted .

Analytical method

☞ Analytical methods are often used. Such as SplitX and LATFW, they have been applied largely in design and assessment of warhead .

- SplitX of CONDAT Company is an expert system for the design of fragmentation warhead.

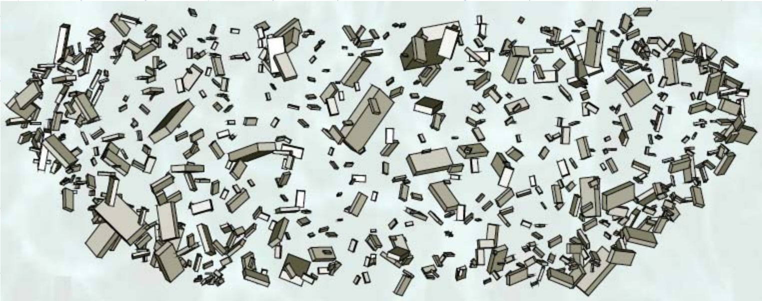
- Assess warhead by analytical method



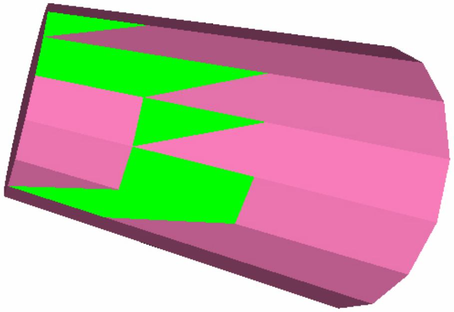
(a) Fragment Velocity Distribution

Analytical method

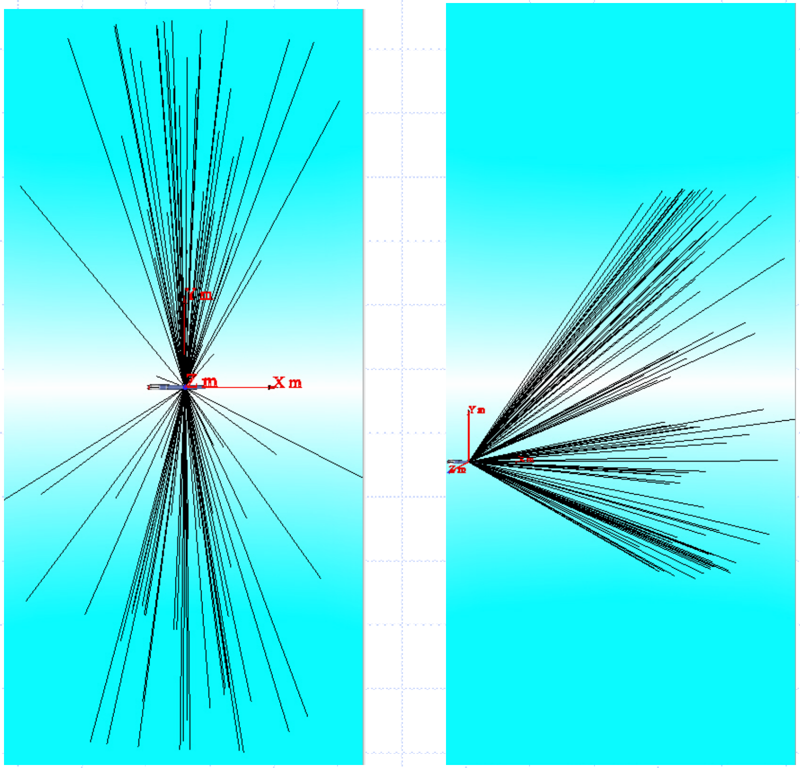
➢ LATFW (Lethality Assessment of Typical Fragmentation Warhead) is achieved by our institute in China.



(a) Fragment fields simulation



(b) damage effect of one cabin



(c) Shotline simulation

Analytical method

- Virtue
  - It can be used to rapidly assess a new or existing warhead design.
  - Warhead design is accomplished based on the method in a short space of time.
- Shortcoming
  - The deviation can be introduced if the methods do not be verified or modified by test data .
  - The methods are limited by specifically condition.

Numerical simulation method

- ☞ The prediction results by the numerical simulation method are more accurate than those by forenamed methods. It can make structural analysis, detonation calculation and so on.
- ☞ The method is fit for the multifarious warheads, such as the axisymmetric warhead and unsymmetrical warhead.
- ☞ Thinking over calculation scale and complication. The method is adopted in one stage of lethality assessment process.

Test method

☞ Early, the lethality assessment method is warhead test. However, a large number of lethality tests may prolong development cycle and increase outlay.

In present, the integrated method including test method, analytical method and numerical simulation method is commonly adopted.

Our Study

- ☞How do we make lethality simulation for fragmentation warhead when efficiency and precision must be considered?
- ☞By integrating Numerical simulation method and analytical method, lethality simulation method for fragmentation warhead is established.
- ☞By numerical simulation method, the fragment initial fields are gained. Based on analytical method, fragment movement model and fragment impact model on target are established.

Our Study

- ☞ The whole process description of fragment field formed, fragment movement, and fragment impacting on target is achieved by using the method.
- ☞ In my topic, I only present my outlook of our study. I want to validate whether the method is feasibility. We analyze the powerful parameters that affect warhead lethality based on example analysis.

LETALITY SIMULATION METHOD

☞ Lethality simulation method of fragmentation warhead consists of numerical simulation model, fragment movement model, lethality parameter model, damage analysis model and fragment field simulation model.

- Fragment initial fields are gained based on numerical results.
- Fragment movement model calculates fragment trajectory. Damage analysis model analyzes fragment damage performance to target.

LETALITY SIMULATION METHOD

- Lethality parameter model analyzes fragment hitting density distribution and the dispersal angle distribution of fragments.
- Fragment field formed, fragment movement, and fragment impacting on target are achieved by fragment field simulation model.

Numerical simulation model

- Numerical simulation model includes numerical simulation and Interface middleware. Numerical simulation is accomplished by LS-DYNA. Because LS-DYNA only outputs node velocity and location, interface middleware is developed to achieve fragment velocity and location. Using interface middleware, fragment initial field is gained and saved.

Fragment No	Location			Velocity		
	X m	*Y* m	*Z* m	*V*x m/s	*V*y m/s	*V*z m/s
1	0.0011	0.6993	0.01557	29.68	2627.00	36.60
2	0.0089	0.7145	0.07378	34.43	2723.90	27.81
……						

File format of fragment initial fields

Numerical simulation model

- Interface middleware is builded based on modified former code. Numerical results are dealed through calling interface middleware, so data exchange between numerical simulation model with fragment movement model.

Fragment movement model

- In fragment movement stage, fragment characteristic parameters are calculated in fragment field. Because of small fragment mass and short fragment trajectory as well as high fragment velocity, fragment gravitational effect is ignored and we assume fragment trajectory is linear.

- Assuming the air drag coefficient is invariable, fragment residual velocity is calculated by

$$V_{\mathrm{r}} = V_0 \exp\left(-\left(\frac{C_{\mathrm{D}} \rho_0 H(Y) A_{\mathrm{s}} g}{2q}\right) r\right)$$

$$C_{\mathrm{D}} = C_{\mathrm{Dsphere}} + \frac{S_{\mathrm{n}} - S_{\mathrm{nsphere}}}{S_{\mathrm{nnature}} - S_{\mathrm{nsphere}}}\left(C_{\mathrm{Dnature}} - C_{\mathrm{Dsphere}}\right)$$

Fragment movement model

- In this analytical model, we don't think over the effect of fragment tumbling.
- In the paper (Fragment Shot-line Model for Air-Defense Warhead, PEP 25, No.2□2000), the analytical model including the effect of fragment tumbling and air drag on fragment trajectory is presented by our team.

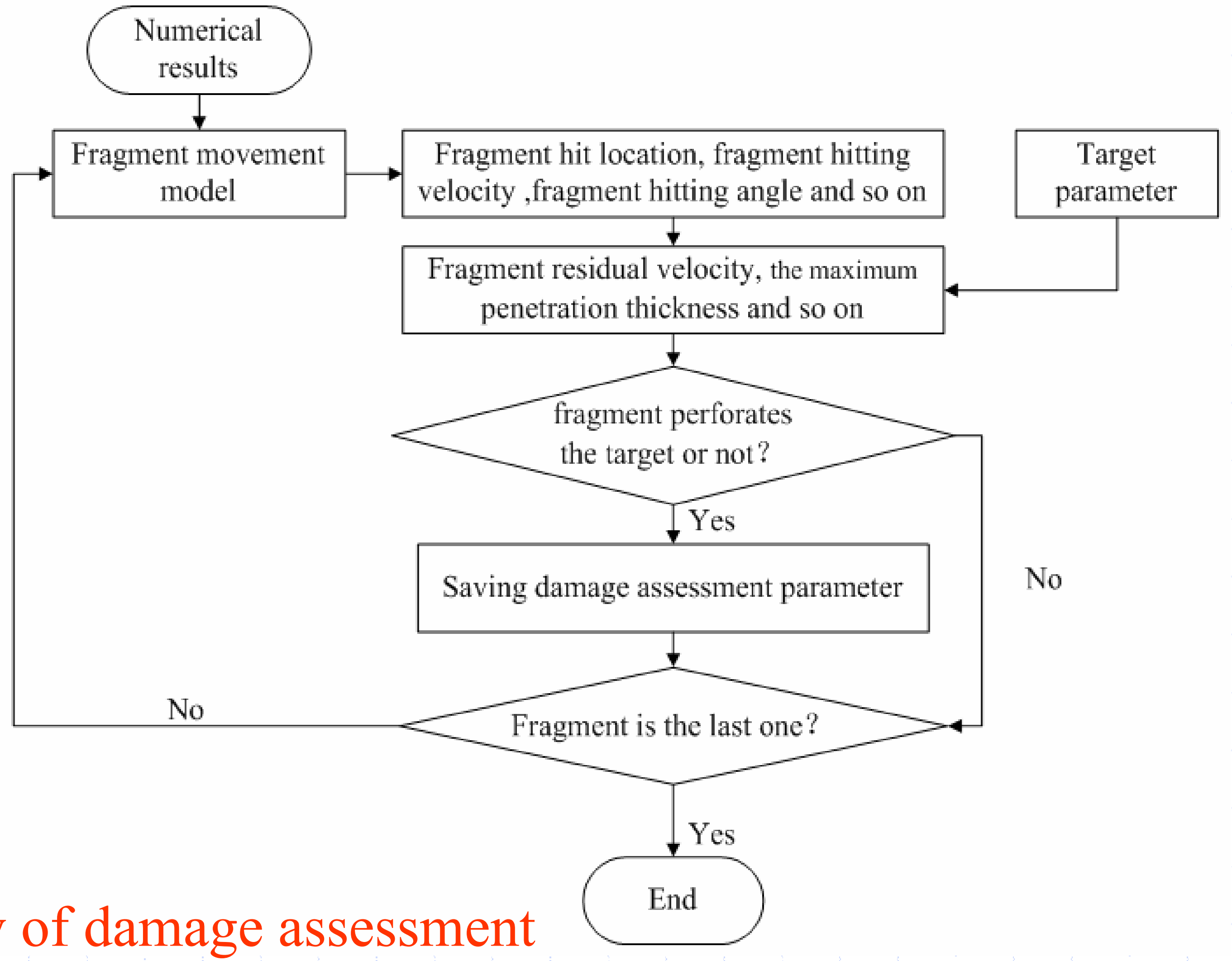
Damage analysis model

- THOR method is adopted to assessment the maximum penetration thickness, the residual mass and the residual velocity.
  - THOR fits for steel fragment impacting on the metallic and nonmetallic target, especially it fits for fragment of high detonator warhead

$$\begin{cases} V_r = V_s - 0.3048 \times 10^{c_{11}} (61023.75hA)^{c_{12}} (15432.1m_s)^{c_{13}} (\sec\theta)^{c_{14}} (3.28084V_s)^{c_{15}} \\ m_r = m_s - 6.48 \times 10^{c_{21}} (61023.75hA)^{c_{22}} (15432.1m_s)^{c_{23}} (\sec\theta)^{c_{24}} (3.28084V_s)^{c_{25}} \end{cases}$$

$$h_{\max} = 1.638706 \times 10^{-5-c_{11}/c_{12}} A^{-1} (15432.1m_s)^{-c_{13}/c_{12}} (\sec\theta)^{-c_{14}/c_{12}} (3.28084V_s)^{(1-c_{15})/c_{12}}$$

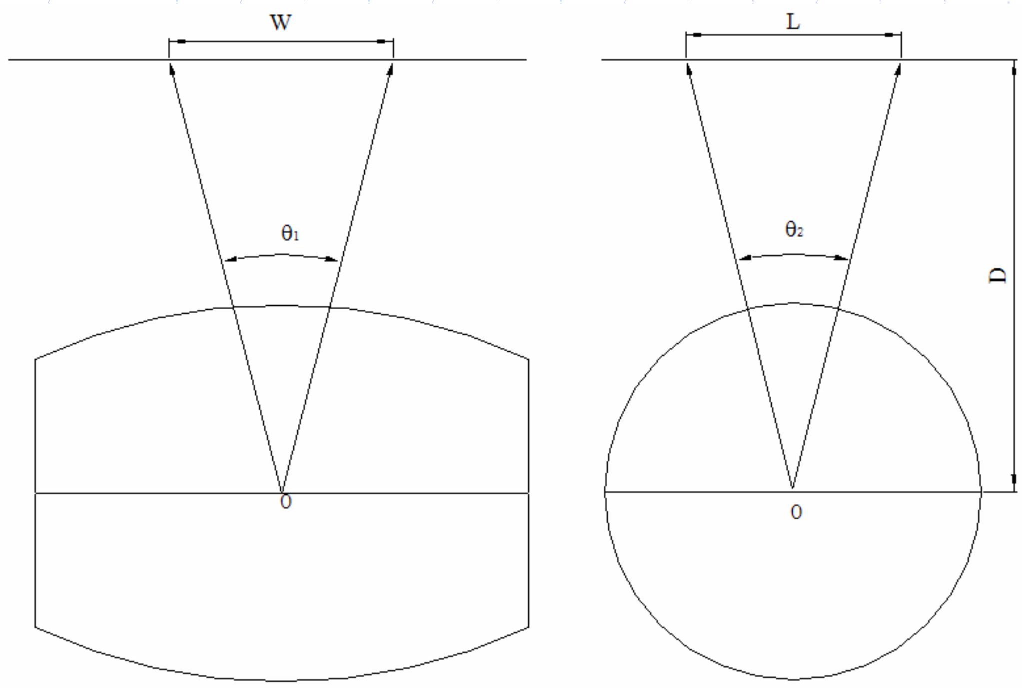
Damage analysis model



Work flow of damage assessment

Lethality parameter model

☞ **Definitions of the variables**



W—Width of statistical area L—Length of statistical area

θ_1—Fragment projection angle θ_2—Warhead radius angle

D—Target distance

Lethality parameter model

- Fragment density is affected by statistical area. In order that statistical results are accurate the length of statistical area is ascertained according to warhead radius angle. According to the dispersal angle of fragments the width of statistical area is calculated, the work flow:

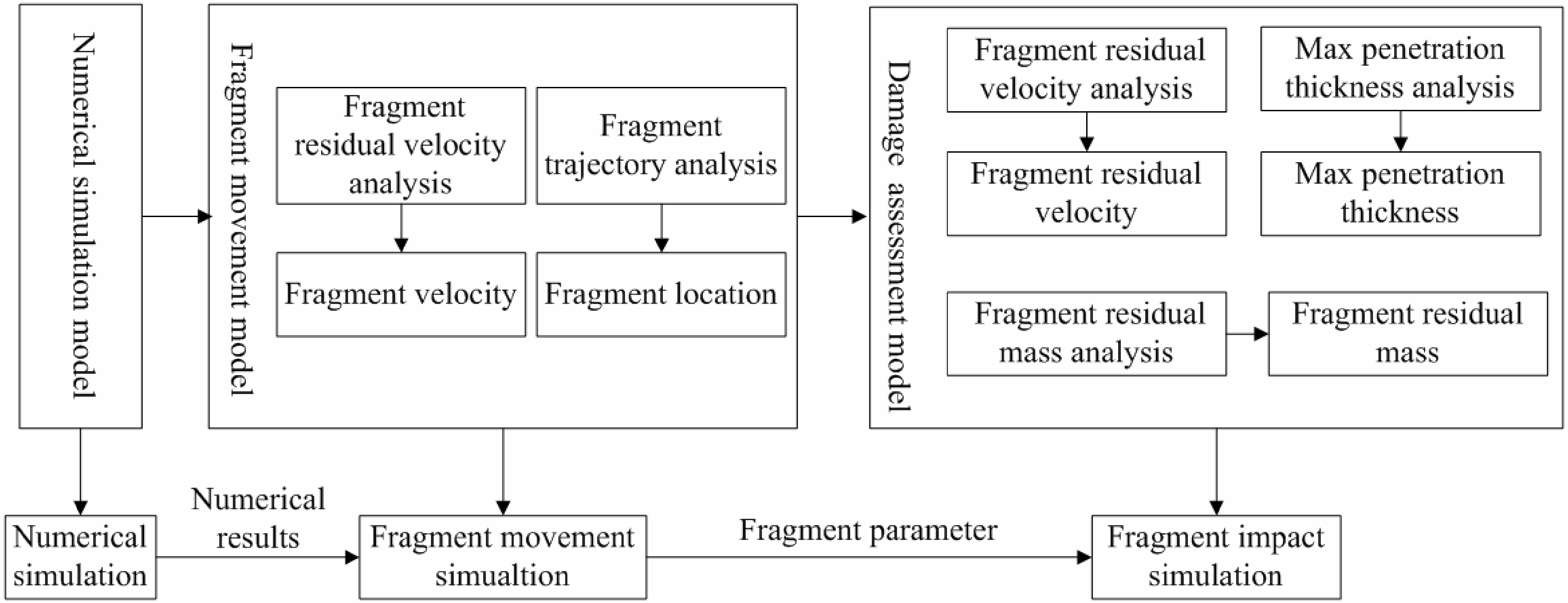
(1) $\theta_1 = 2\arctan(\frac{W}{2D})$ (2) $L = 2D \cdot \tan(\frac{\theta_2}{2})$

(3) $\rho = \frac{0.9N_{\text{frag}}}{L \times W}$

(4) Based on warhead radius angle the statistical number is ascertained, for the whole target. Fragment density of each statistical area is gained by the step(1)~(3)□

Simulation model

- System simulation model divides into three stages.



System simulation model

Simulation model

- System simulation model calculates trajectory, velocity , residual velocity and residual mass.
- In order to investigate fragment field in different time simulation data is saved, and fragment field simulation is displayed in other CAD software.

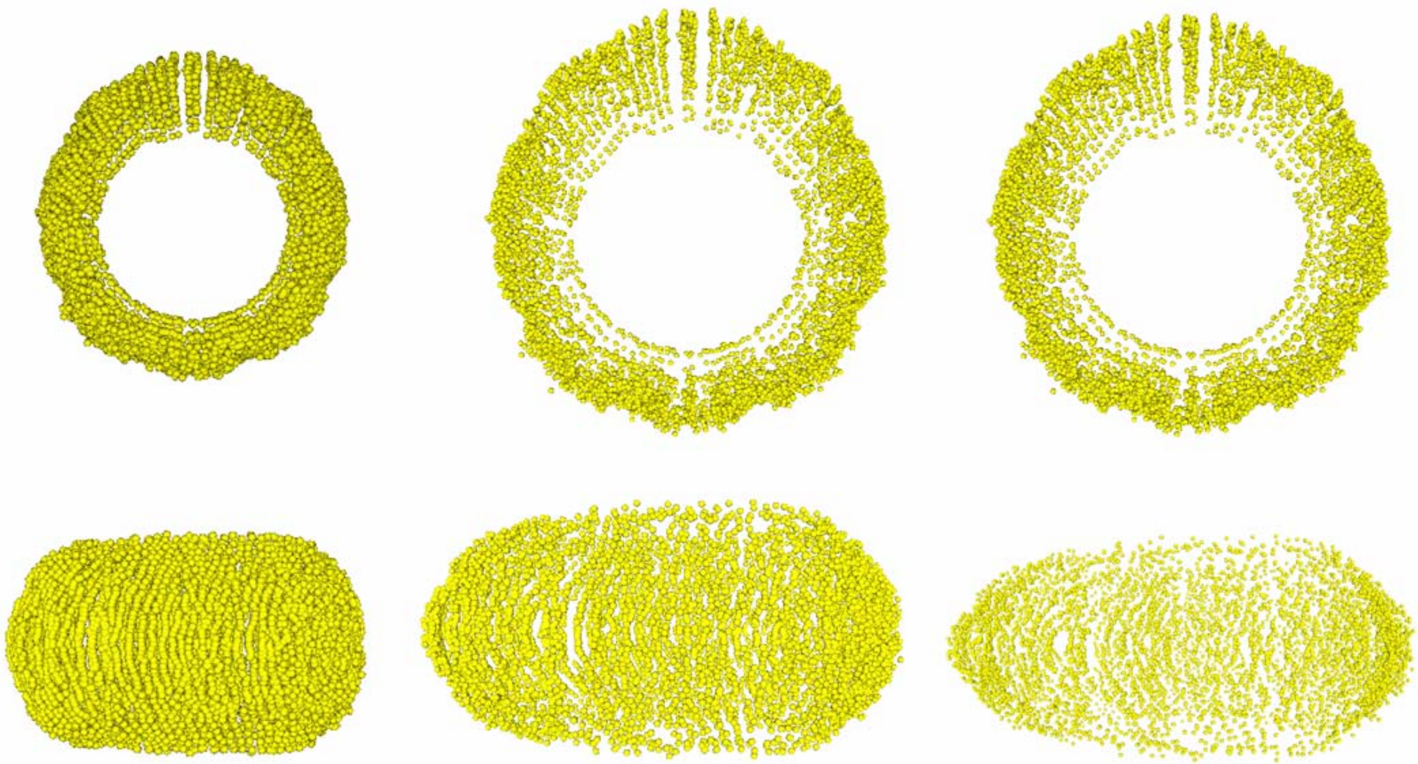
EXAMPLE ANALYSIS

On the basis of the simulation method, lethality simulation code is developed. One example of an aimable warhead is examined.

- System visualization
- Analysis of fragment density
- Analysis of fragment projection angle

System visualization

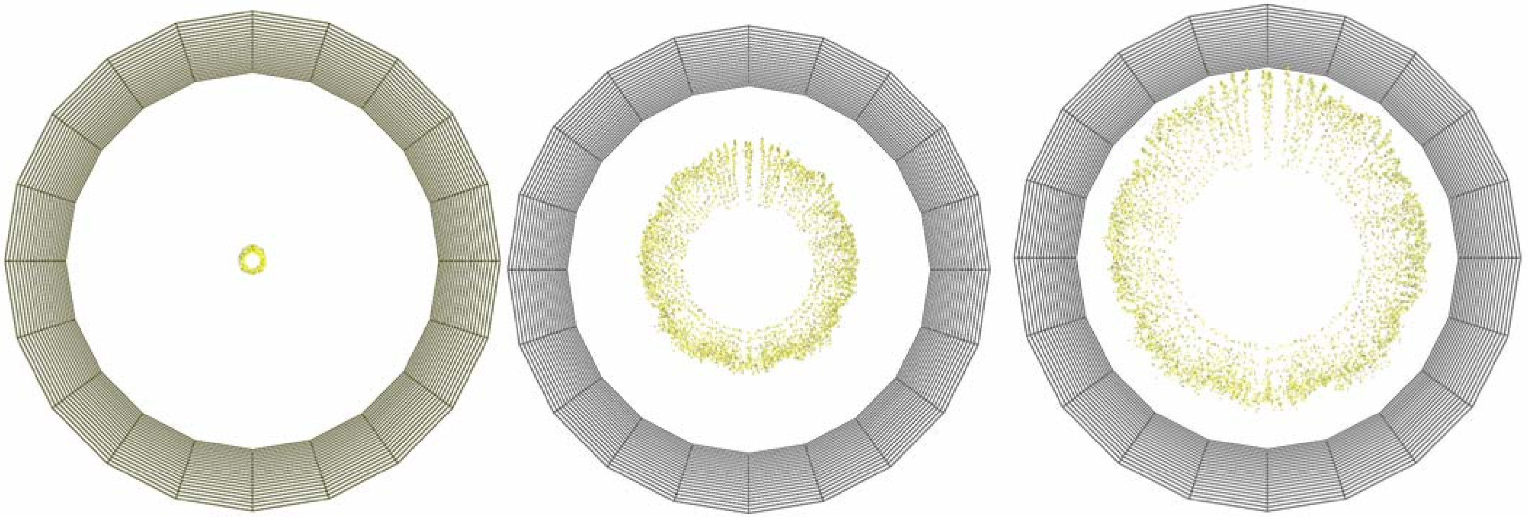
- Fragment field simulation



(a) $\tau = 0.25$ ms (b) $\tau = 0.46$ ms (c) $\tau = 0.80$ ms

System visualization

☞ **Fragment field simulation**

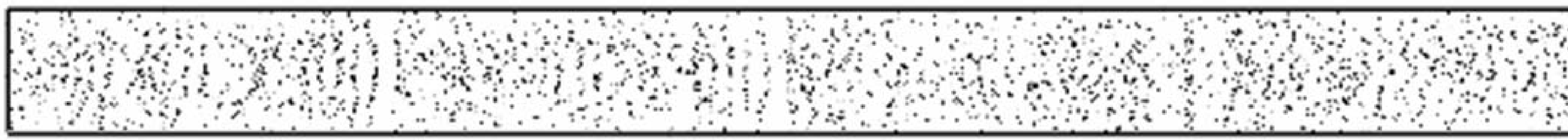


(a) 0.25 ms (b) 1.98 ms (c) 2.88 ms

➢ The aimable area is not obvious at 0.25 ms. The fragment velocity in aimable area is higher than those in non-aimable area at 2.88 ms. Aimable fragments firstly hit target.

System visualization

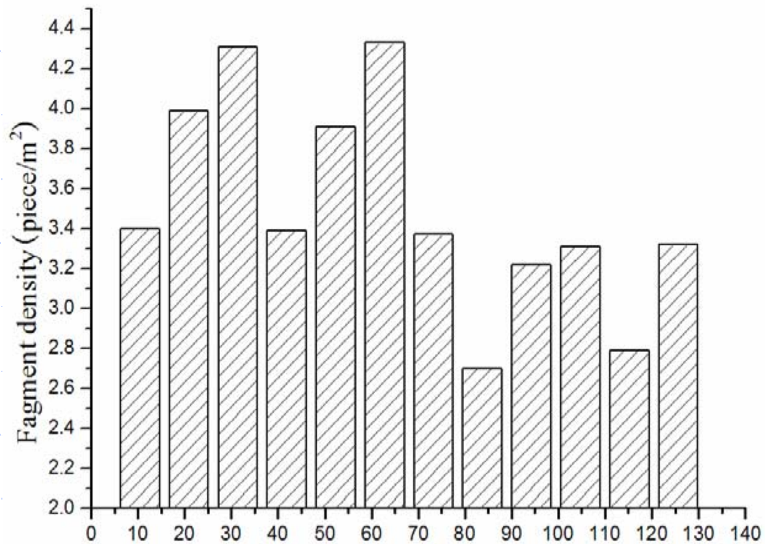
☞Fragment field simulation



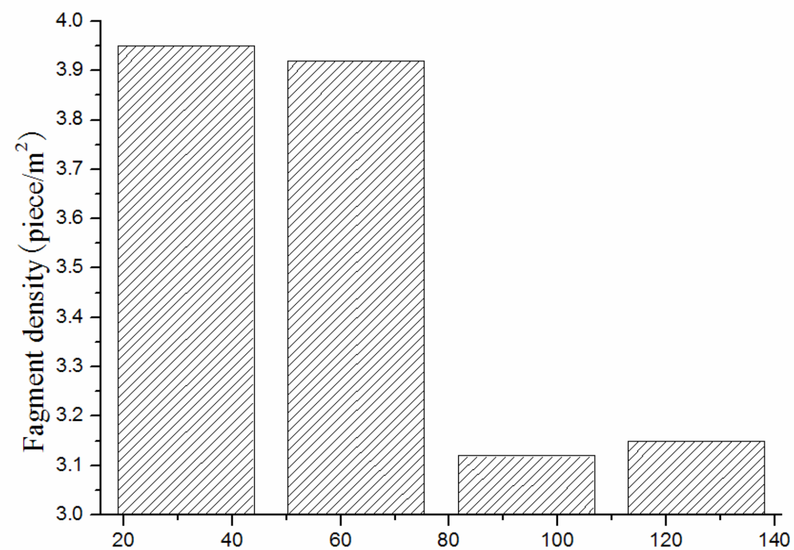
➢This graph shows visualization graph of fragment distribution on target. Target height is 10m and target distance is 20m. The circle target is unwrapped in order to represent fragment distribution clearly.

Analysis of fragment density

☞Two cases



$\theta_2 = 30^\circ$



$\theta_2 = 90^\circ$

- At 30° fragment density fluctuates heavily in each statistical area, The aimable area is not obvious.
- At 90° the aimable area is obvious.

Analysis of fragment density

☞Results

- According to the analytical results, the variational trend of fragment density is similar when θ_2 is same even if the target distance is different.

- Suppose fragment trajectory is linear, when θ_2 is same fragment density is in inverse proportion to the square of target distance that is match with analytical results.

Analysis of fragment projection angle

- Considering the relationship between fragment projection angle and warhead radius angle, fragment projection angle corresponding is the average value of projection angle in different statistical area.

- Fragment projection angle is not sensitive to θ_2 and the statistical error is less than 1°. Fragment projection angle ranges from 42° to 43°.

Analysis of fragment projection angle

☞Results

- ➢Fragment projection angle in different statistical area fluctuates when θ_2 is same.
- ➢At the same time fragment project angle fluctuates with the change of warhead radius angle but the extent is small.
- ➢Fragment project angle distribution of aimable warhead is unsymmetrical and fluctuates heavily. The factor must be considered. It's better to point out which area projection angel is in aimable area, non-aimable area or all the area.

CONCLUSION

☞Lethality simulation method includes numerical simulation and theoretical analysis, so the method fits for different kinds of the warhead by generalizing it.

☞ Based on the method, lethality simulation system is constructed, and numerical simulation of fragmentation warhead lethality are achieved by the system, and analytical results are directly applicable for warhead lethality assessment.

☞ Based on the test, the method is an effective method of validating numerical simulation.

FUTURE WORK

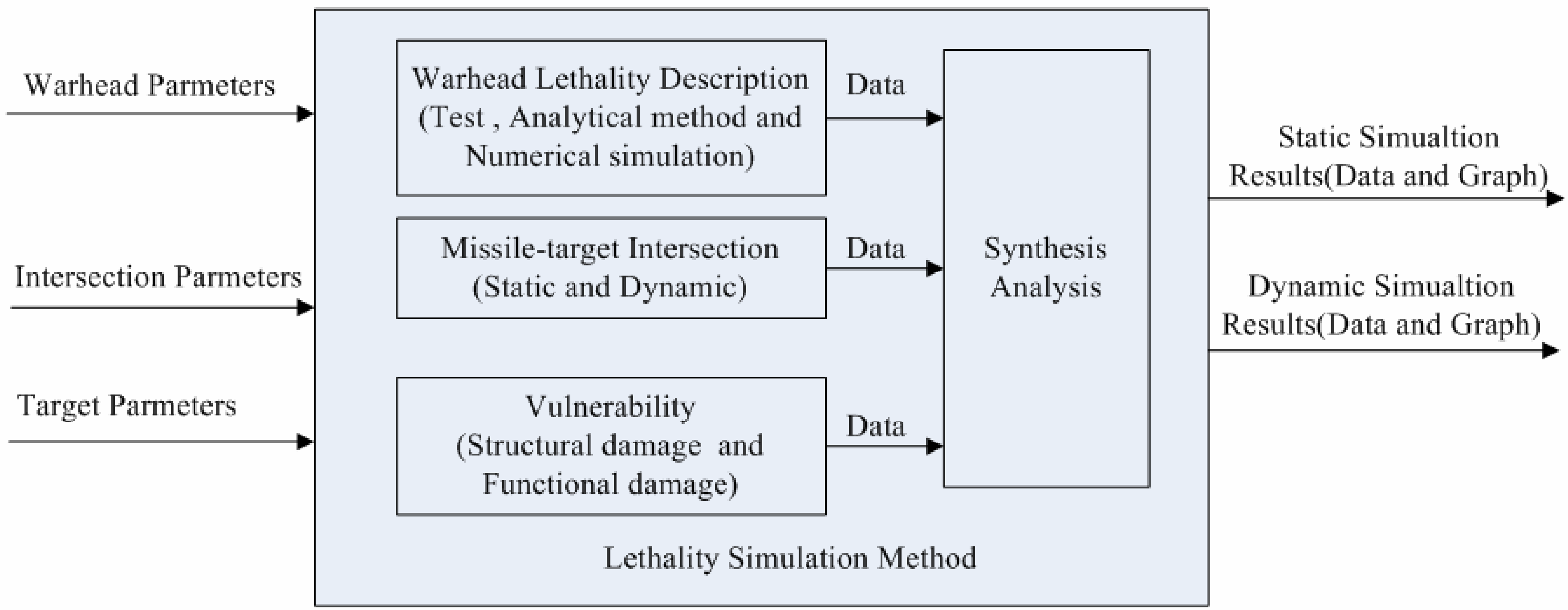
- How to assess Virtual Prototyping (Numerical Products) of warhead thinking over precision and efficiency?
- How to integrate lethality assessment and warhead design, and establish the compositive design environment of warhead study.
- Our thinking
  - Lethality simulation method and code are studied by integrating analytical method, numerical simulation method in warhead lethality description, missile-target intersection and vulnerability.

FUTURE WORK

- Warhead lethality description
  - Warhead lethality description for different kinds of the warhead is studied by the integrated method.
- Missile-target intersection
  - Static intersection → Dynamic intersection.
- Vulnerability
  - Vulnerability analysis method is traced and analyzed.
  - Structural damage and functional damage.

FUTURE WORK

☞Lethality Simulation Code



➢This code is easy to integrate with the compositive design environment.

THANKS

Thank you for your attention!